during the last few years have been greatly impeded by the restricted nature of the firmans granted, and constant disputes were arising as to the area over which the firman extended. Mr. Rassam has succeeded in obtaining a series of sufficiently open permits to enable the new expedition to assume the nature of a roving exploring party. The new firman includes the whole of Mesopotamia, embracing the region around Mosul—that is, the sites of Nineveh, Kalakh, and the ancient city of Assur, the site of which is marked by the mounds of Kileh Shergat. A special firman has been obtained to enable Mr. Rassam to commence explorations in a hitherto untouched field—the dis. tricts of North-Eastern Syria. This region, the country which once formed the seat of the powerful Hittite kingdom, having for its capital the city of Carchemish, is as yet a *terra incognita* to explorers, and as its annals when discovered will form an important link in the chain of history which binds Assyria to the West, great results may be expected from Mr. Rassam's explorations in this district.

WE have on our table the following books:—"Pleasant Ways in Science," R. A. Proctor (Chatto and Windus); "Ancient History from the Monuments of Sinai," S. H. Palmer (S.P.C.K.); "Crystallography," H. P. Gurney (S.P.C.K.); "Bluthendiagramma," 1st and 2nd Parts, Dr. A. W. Eichler (Engelmann); "Studies from the Physiological Laboratory of University of Cambridge" (University Press).—London Science Class-Books (Longmans):—"Botany, Morphology, and Physiology," W. R. McNab; "Botany: Classification of Plants," W. R. McNab; "Hydrostatics and Pneumatics," P. Magnus; "Invertebrata and Vertebrata," Prof. Macalister; "Motion of the Moon," Dr. S. Newcomb (Washington); "Physical, Geological, and Geographical Map of Great Britain," Prof. Ramsay (Standford); "Meteorology of the Bombay Presidency," Charles Chambers; "Karl Ernst von Baer," Dr. Stieda; "Karl Friedrich Gauss, Hauptmann (E. J. Brill); "Report on Iron and Steel as Manufactured by Messrs. Jones and Laughlins," R. H. Thurston; "On the Equilibrium of Heterogeneous Substances," Parts 1 and 2, J. W. Gibbs; "Skizzen aus West Afrika," Oskar Lenz (A. Hofmann); "Les Produits de la Nature," A. J. C. Geertz (C. Lèvy); "La Prévision du Temps," W. de Fonvielle.

THE additions to the Zoological Society's Gardens during the past week include a Cross Fox (*Canis fulvus*) from Colorado, presented by Mr. Wilfred G. Marshall; a Common Otter (*Lutra vulgaris*), European, presented by Mr. W. H. Baylis; a Brown Mynah (*Acridotheres fuscus*), a Pied Mynah (*Sternopastor contra*) from India, an Indranee Owl (*Syrnium indranee*) from Ceylon, presented by Capt. J. Murray; four Egyptian Geese (*Chenalopex ægyptiaca*) from the Cape of Good Hope, presented by Mr. Justice Denyssen; two Leopard Tortoises (*Testudo pardalis*) from the Cape of Good Hope, presented by the Rev. G. H. R. Fisk, C.M.Z.S.; a Collared Peccary (*Dicotyles tajaçu*) from South America, deposited; a Red-Sided Eclectus (*Eclectus polychlorus*) from Malacca, a Black-Footed Penguin (*Spheniscus demersus*) from the Cape of Good Hope, four Chinese Turtle-Doves (*Turtur chinensis*) from China, purchased; a Hybrid Mandrill Monkey (between *C. mormon* ♀ and *M. cynomolgus* ♂), an Indian Muntjac (*Cervulus muntjac*), born in the Gardens.

ON THE PRESENCE OF DARK LINES IN THE SOLAR SPECTRUM WHICH CORRESPOND CLOSELY TO THE LINES OF THE SPECTRUM OF OXYGEN[1]

THE measurement of the wave-lengths of the dark lines of the solar spectrum obtained by photographs, and the construction of a chart of the same, has for many years occupied my leisure time. As a result of the investigations connected with this work, I have arrived at the belief that oxygen as well as other non-metallic gaseous elements are represented in the solar spectrum by dark lines in the same manner as metallic substances. The lines in the case of oxygen are, however, very faint when compared with those produced by metals in the vaporous state.

The apparatus employed in these investigations may be briefly described as follows: 1st, a spectroscope for photographing the normal solar spectrum. As my purpose was to obtain photographs in which the positions of the lines should be as true as possible, I resorted entirely to the process by reflection, *and at no time did the solar rays pass through glass*; all error that might arise during refraction was thus avoided. The mirrors of the heliostat were of flat glass silvered, the silver-surface being polished served as the reflector. The surface of the concave-mirror employed to bring the image of the slit to a focus, was also silvered and polished. Gratings of 4,800 and 9,600 lines to the English inch, ruled on glass by a machine constructed by myself and by my assistant Mr. Sickels, and also an admirable one of 17,280 lines to the inch, for which I am indebted to Mr. Rutherfurd, were used. These were silvered with a thin coating, and the unpolished silver surface employed to give spectra by reflection. With the 4,800 line gratings the photographs were in the 1st and 3rd orders; with those of 9,600 lines in the 3rd order, and with 17,280 in the 1st and 2nd orders. The accuracy of the gratings was tested with satisfactory results by taking photographs in equivalent orders of spectra on each side of the normal. The photographs for the determination of the wave-lengths of the solar spectrum were in sections of eighty to one hundred and fifty wave-lengths. The gratings were adjusted to the line of no deviation for the centre of each section of the spectrum, as it was photographed.

The wave-lengths of the lines of the spectrum were carefully measured on the original photographs, by projecting them upon a scale of wave-lengths, each wave-length being five millimetres in extent. The scale was drawn upon slips of paper, which had been glued to strips of well-seasoned pine wood cut with the grain. The lantern used for projection was that described in this journal for April, 1878. The distance of the lantern from the scale, and the consequent magnifying power, was so adjusted as to make the leading lines of the photograph coincide with the same lines of Ångström, drawn in their proper position below the scale as is shown in the diagram given later on. Thus the positions of the lines in each section of one hundred or more wave-lengths were all made visible at once, and the errors in Ångström's chart corrected. From 4045 to 0 in the ultra-violet the leading lines of Cornu were employed. Among the advantages presented by this method of studying and measuring the lines of the spectrum we may mention the opportunity offered for several persons to inspect at the same time the details of the section under examination, and submit them to intelligent discussion. To this we may add the facilities offered for comparing many photographs with each other by marking below the scale the peculiarities of one, and then projecting the others in order upon the marks made. In this way the effects of duration of exposure and manner of development of the image, together with the variation in the size of the slit and focal distance may be investigated, and their action on the details of the picture determined. Pictures may even be placed face to face, one a little above the other, and examined in that position by projection. From the measures thus obtained a chart of the spectrum was constructed, which extended from E in the green to P in the ultra-violet. The values assigned to the wave-lengths in this chart are those of Ångström, and it is my purpose to present the positions and characters of certain of these lines in this communication.

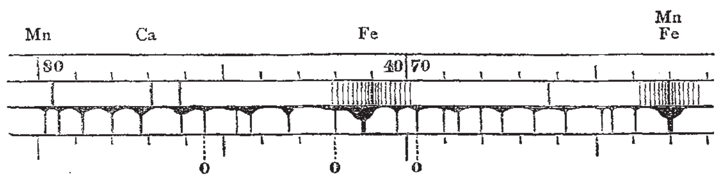
The great increase in the number of lines in the chart made from photographs by Mr. Rutherfurd's grating, compared with that of Ångström, led me to collect all the measurements of spectrum lines of elements that I could find, for the purpose of determining the character of the newly-measured lines. On comparing the lines of the spectra of oxygen, nitrogen, and air, as given in Watt's index of spectra, from the researches of Thalén, Huggins, and Plücker, I was struck with the number of approximate coincidences between the wave-lengths of oxygen lines and those of dark lines in my map. Attempting to make a close comparison of the oxygen with the solar lines I was confronted by the following difficulties, viz.: the measurements

[1] By John Christopher Draper, M.D., LL.D., Professor of Natural History in the College of the City of New York. From the *American Journal* for October.

of Thalén, Huggins, and Plücker were given in wave-lengths only, fractions being omitted altogether. Error amounting to half a wave-length could therefore exist in the position of a line, according as it fell on one side or the other of a figure on the scale expressing a wave-length. In the values given to the air-lines by Ångström in his chart, this difficulty did not exist; I therefore attempted the use of Ångström's values, employing the work of Huggins and Plücker, to separate as far as possible the oxygen from the nitrogen lines. This operation was, however, quickly discarded; because of the great differences existing between these authorities regarding the wave-lengths of a number of oxygen and air-lines. To obviate this trouble, I made photographic measurements of the lines of the electric spectrum of oxygen by the method detailed below.

The apparatus employed consisted of a spectroscope with two flint glass prisms of 60°, adjusted to the minimum deviation of D′. Collimator and telescope objectives, achromatics of ten inches focus. This was used to make photographs of the spectra given by the condensed electric spark in oxygen, in air, and in nitrogen. When so employed the eye-piece of the telescope was removed, and a camera placed in its stead. The slit was sometimes made as narrow as was possible. The induction-coil was one of Ritchie's, giving a ten-inch spark, and having a hammer current-breaker driven by clock-work. The battery was three two-gallon bichromate cells, the elements were large, but just touched the fluid when the battery was in operation. The large mass of fluid in proportion to the immersed area of the elements served to supply a very uniform primary current. The condenser on the secondary current consisted of ten glass plates, each having a tin-foil coating of thirty-six square inches. One or more of these plates could be thrown into the circuit as occasion required. By this arrangement a number of photographs of the electric spark, between platinum and iron points, in atmospheres of oxygen, and of oxygen and nitrogen, were made. The positions of the iron and oxygen lines in these were measured, as in the solar photographs, by projection under a suitable magnifying power. The centre of each line was the portion from which measures were taken in all cases. The wave-lengths of the oxygen-lines were then determined by means of a curve, which from λ3864 to λ4414·75 was based on the iron lines of the same spectrum. In all forty-seven iron lines in this extent of the spectrum, or about one to every eleven wave-lengths were used. The values assigned to the iron lines were those obtained in my chart of the solar spectrum. By this method of measurement errors arising from maladjustment of two spectra were avoided. From λ4414·75 to λ4705 the iron lines did not photograph; I was therefore obliged to construct this portion of the curve from the wave-lengths of oxygen and air-lines already given by various authorities, selecting those values in which they agreed. From 3864 to 4414·75 the results are therefore accurate. From 4414·75 to 4705, though they are approximate, the error, if any exists, must be very small. The measurements to fractions of a wave-length were obtained by constructing the curve on a scale of sufficient magnitude.

In illustration of the great number of lines presented by my chart of the solar spectrum, as compared with that of Ångström, I give a small section extending from 4062 to 4080, within which the oxygen group 4069·80—4072·10—and 4075·50 falls. On the upper part of the diagram the symbols of the elements are placed, to which, according to Ångström, corresponding lines are found in the solar spectrum. On the first space below the line is the scale of wave-lengths, each wave-length being five millimetres in extent. In the second space the lines of Ångström's chart are given. In the third space the lines measured on the photographs, the vertical portion of each symbol giving the position, and the horizontal portion the width, and also the darkness on an arbitrary scale of one to ten. The darkest lines encroach most on the vertical portion of the symbol. The value 10 is expressed in the symbol of the Mn Fe line 4063, and the value 1 in that of the line 4068·05. Other features of the lines are shown by the manner in which the upper part of each of these symbols is drawn. Beneath the spectrum-lines the scale is repeated, and the position of the



oxygen lines indicated. In addition to the lines already mentioned as being in Ångström's chart, lines of the following elements appear in this space, viz., Fe 4063, Pb 4066, Sr 4078, Bi 4080. The correspondence between these values and the wave-lengths of the lines in the photographic spectrum is as close as could be expected, seeing that the authorities do not give fractions of wave-lengths. The Te line is represented in the spectrum by the Mn Fe line 4063, the Pb line by the spectrum line 4065·7, the Sr line by the line 4077·9, and the Bi line by the line 4079·8.

Inspection of the diagram also shows that, while the Mn Fe 4063 lines are coincident in both charts, the Fe line 4071 of Ångström reads 4071·25 in the photographic chart, and the unassigned line 4076·25 of Ångström reads about 4076·20, in my chart, the two lines being nearly coincident. In the photographic chart the relations of the lines to each other as regards position are accurately presented, and where these differences occur the positions given in the photographic chart must be correct. The total number of lines in the two charts is also worthy of notice. In the eighteen wave-lengths represented in the diagram Ångström gives six lines, while the photographic chart gives twenty-four. Of Ångström's lines five are assigned to different metals, if we give the line 4066·25 to Pb, and one is unassigned. In the photographic chart these lines also appear, and in addition the lines of Bi and Sr, together with the three oxygen lines. Out of the twenty-four lines ten are assigned to various elements, leaving fourteen to be accounted for, and many of these are moderately strong lines. The oxygen lines represented in the diagram are among the strongest in the electric spectrum of oxygen, yet the equivalent lines in the solar spectrum are faint when compared with the lines of Ca and Fe. This would seem to indicate a low absorbing power in the gaseous non-metallic elements, as compared with the same power in the case of metals in the vapourous state. The existence of a difference like this would explain why it is that many of the lines in the solar spectrum which represent oxygen have been overlooked. Some of these lines have, however, been observed, Ångström himself giving in his chart a number of lines not assigned by him nor any one else to other elements, which are very nearly coincident with the oxygen lines, as determined by the photographic method, as will be seen in the table at the close of this article.

As it is not possible, in the space to which we are limited, to give diagrams of all the portions of the solar spectrum which contain oxygen lines, we present in the following table the positions in that spectrum of all the oxygen lines that were obtained in the photographs of the electric spark in that gas. The first column contains the wave-lengths of certain lines in the chart made from photographs of the solar spectrum; the second the wave-lengths of the lines of the condensed electric spark in oxygen; the third Plücker's lines of oxygen, which are much more numerous than those of Huggins, which are presented in the fourth column, while the fifth column gives the lines of Ångström's air spectrum, which may be credited to oxygen. The term free in the first column is used to indicate the fact that no element has heretofore been found to give a line within two or three tenths of a wave-length of that position. It is therefore free to be assigned as an oxygen line. The chemical symbols on the other lines show that the element indicated has been assigned to that line, and shares it with oxygen. The number of lines of greater wave-length than 3961·60, which are free from other elements, and which are assignable to oxygen, is good evidence of its presence in the solar envelopes.

DRAPER. Lines of photographic chart of solar spectrum, with their condition.	DRAPER. Lines of electric spark in oxygen.	PLÜCKER. Lines of oxygen.	HUGGINS. Lines of oxygen.	ÅNGSTRÖM. Lines of spark in air attributed to oxygen.
3864·50^{2} free.	3864·75^{1}			
3882·30^{9} ,,	3882·30^{3}			
3907·90^{2} ,,	3908·00^{1}			
3912·25^{3} ,,	3912·35^{3}			
3919·75^{3} ,,	3919·50^{2}			
3945·10^{1} ,,	3945·10^{3}			
3954·60^{3} ,,	3954·70^{7}			
3961·60^{4} ,,	3961·60^{2}			
3973·40^{3} ,,	3973·50^{10}			
3982·75^{1} ,,	3982·70^{3}			
3995·50^{3} ,,	3995·50^{5}			
4069·80^{2} ,,	4069·50^{10}	4069·00^{3}	4069·00^{3}	4069·50
4072·10^{3} ,,	4071·90^{10}	4072·00^{3}	4073·00^{3}	{4071·65 4073·65
4075·50^{2} ,,	4075·45^{10}			4075·50
4084·70^{4} ,,	4084·80^{5}	4085·00^{4}		
4088·00^{1} ,,	4087·80^{4}	4086·00^{2}		
4093·20^{1} ,,	4093·10^{4}	4094·00^{2}		
4104·40^{2} ,,	4104·50^{6}	4104·00^{2}		4103·00
4111·00^{2} ,,	4111·10^{4}			
4118·00^{7} Fe.	4118·20^{10}	4117·00^{2}	4117·00^{2}	
4121·20^{3} ,,	4121·20^{6}			
4133·00^{3} free.	4132·90^{6}	4126·00^{6}		
4142·90^{7} Fe.	4142·90^{6}	4135·00^{6}		
4145·30^{2} free.	4145·50^{7}	4147·00^{2}	4149·00^{2}	
4152·90^{1} ,,	4153·00^{8}			
4155·60^{1} ,,	4155·75^{4}	4158·00^{4}		4155·00
4168·20^{1} S.	4168·40^{4}	4171·00^{2}		
4184·90^{1} free.	4185·00^{8}		4183·00^{5}	4184·50
4189·90^{1} C.	4190·00^{10}	4190·00^{5}		4189·60
4254·30^{1} free.	4254·50^{3}			
4274·80^{4} CrCa.	4275·00^{6}			
4278·10^{3} Pb.	4278·10^{6}			
4303·00^{5} free.	4303·00^{4}			
4316·60^{2} ,,	4316·50^{8}			
4320·00^{4} TiC.	4319·75^{8}			
4325·10^{10} Fe.	4325·20^{6}	4327·00^{2}		
4328·10^{1} Bi.	4328·20^{4}			
4331·00^{2} free.	4331·20^{4}			
4336·34^{4} SCr.	4336·00^{6}	4334·00^{2}		
4345·15^{2} free.	4345·20^{9}	4341·00^{6}		4345·80
4348·20^{2} ,,	4348·30^{10}	{4347·00^{10} 4348·00^{10}	4347·00	4347·50
4353·00^{2} ,,	4553·10^{8}			
4365·00^{1} BrCe.	4365·20^{8}		4364·00^{4}	
4369·10^{4} CrFeAs.	4369·20^{4}	4369·00^{4}		
4394·50^{3} free.	4394·50^{4}			
4413·20^{2} ,,	4413·20^{10}	4414·00^{8}	4414·00^{8}	4414·60
4417·85^{3} ,,	4418·00^{10}	4418·00^{8}	4416·00^{8}	4418·30
4445·00^{2} ,,	4445·00^{6}	4443·00^{4}		
4450·00^{2} Mn.	4450·00^{3}	4450·00^{4}		
4463·00^{2} Ce.	4463·00^{8}	4457·00^{4}		
4467·30^{1} Ce?	4467·20^{8}	4468·00^{10}	4467·00^{10}	
4483·80^{1} Fe.	4483·75^{3}	4474·00^{10}		
4572·10^{3} Be.	4572·20^{1}			
4577·75^{6} Ce.	4577·55^{1}			
4582·10^{2} FeCe.	4582·10^{1}			
4589·30^{4} free.	4589·50^{10}		4588·00^{6}	4590·80
4595·40^{3} ,,	4595·50^{10}	4593·00^{6}	4596·00^{6}	4595·90
4599·80^{3} 4600·15^{4} {Sb. C.P. Cr.	4600·00^{3}	4600·00^{6}		
4629·60^{3} free.	4629·60^{4}	4639·00^{10}		
4640·50^{3} ,,	4640·20^{10}	4640·00^{10}	4640·00^{6}	4640·25
4648·15^{4} Cr.	4648·15^{10}	4649·00^{8}	4648·00^{8}	
4661·50^{4} free.	4661·50^{8}	4662·00^{7}	4662·00^{7}	
4674·90^{1} CSe?	4675·00^{8}	4675·00^{7}	4677·00^{7}	4674·75
4698·65^{3} free.	4698·50^{10}	4698·00^{7}	4699·00^{7}	4698·00
4704·65^{1} Ba.	4705·00^{10}	4705·00^{7}	4706·00^{7}	4706·50

The table presents what may be called the oxygen region of the spectrum, only a few oxygen lines lying outside of its limits. As this also happens to be the region in which our photographic apparatus and chemicals were most sensitive, we are enabled to present measurements of the majority of the lines of oxygen. It will be noticed that though the oxygen lines of greater wave-length than 4704·65 are wanting, on account of their lack of photographic power, this loss is partly made up by the extension of the measurements into the ultra-violet region, where as yet no exact measurements of oxygen lines have been made that I am aware of.

That there should be no error regarding the nature of the chemical element producing the lines, every precaution was taken to have the oxygen as pure as possible. Photographs of the spark in oxygen, between points of the purest platinum that I could procure, were also made. These were compared with the measured photographs of the spark between an iron and a platinum terminal, and provision was thus made for the detection of any error that might have arisen from impurity in the iron used in the terminal. As these photographs of the spark between platinum terminals in pure oxygen presented all the lines given in the table, these lines may be regarded as true oxygen lines. In addition to the oxygen lines given, the following feeble lines were observed, regarding the nature of which I was not quite satisfied, as they did not pass entirely across the spectrum, viz., 4490·30—4505·80—4525·50—4548·75. In the space extending from 4254·30 to 4345·15, many of the oxygen lines are assigned to wave-lengths occupied by other elements; for example, Cr, Ca, Sb, Ti, C, Bi. As other lines of these elements did not present themselves in the measured photographs, and as the lines in question were also found in the photographs of the spark between platinum terminals, they are to be regarded as true oxygen lines, although they are not given by other authorities. In some of the instances in which elements in addition to oxygen are assigned to a weak line in the solar spectrum, it is very possible that such assignments are in error, because of a lack of fractions in the determinations of the wave-lengths of these additional elements. Apparent discrepancies regarding wave-lengths in my determinations, and those of the other authorities, are sometimes explained by the fact that a line which is recorded as single in one case, is given as two lines in the other. It is also worthy of remark that in almost every instance in which a line is presented by one authority and omitted by the others, it is to be found in the column containing the photographic determinations, and is an evidence of the superiority of this method of recording the existence and positions of spectrum lines throughout the region over which it can act.

Examination of the table shows that the differences between the wave-lengths obtained for the lines of the electric spectrum in oxygen and the lines of the solar spectrum are very small. Out of the sixty-five lines of the solar spectrum which are, as we have seen, assignable to oxygen, in seventeen the coincidences are absolute; in four the difference is only five one-hundredths of a wave-length; in twenty-two, ten one-hundredths of a wave-length; in four, fifteen one-hundredths of a wave-length; in eleven, twenty-one one-hundredths of a wave-length, and in the remainder the greatest difference is only thirty-five one-hundredths of a wave-length, or about that which Ångström has made in different measurements of the same line in the solar spectrum.

The small figure attached as a power to each wave-length of the electric and solar spectra in the table is a proximate expression of the photographic strength of that particular line in each spectrum, and an examination of these upholds the statement made in a preceding paragraph that the oxygen lines of the solar spectrum are very weak when no other element furnishes a line which falls on the same wave-length. Of course photographic must not be compared with visual intensities, for as the one diminishes in the less refrangible regions of the prismatic spectrum the other increases. An example of coincidence in the lines of different elements, and consequent increment in strength, occurs in the line 4118, and probably in the line 4303 also, though it is supposed to be free.

In conclusion, I give a list of certain lines in Ångström's chart which have not as yet been assigned to any element, together with the wave-lengths of the same lines in my solar and electric spectra. From this table it will be seen that Ångström himself observed a number of lines, the relations of which to elementary bodies no one has as yet demonstrated, and which I believe represent the oxygen in the solar envelopes.

Table of Free Lines in Ångström's Solar Spectrum which may be attributed to Oxygen.

Draper's electric spectrum of oxygen.	Draper's solar spectrum.	Ångström's solar spectrum.
$4132{\cdot}90^{6}$	$4133{\cdot}00^{3}$	$4133{\cdot}20^{2}$
$4155{\cdot}75^{4}$	$4155{\cdot}60^{1}$	$4155{\cdot}80^{2}$
$4254{\cdot}50^{3}$	$4254{\cdot}30^{1}$	$4254{\cdot}55^{3}$
$4303{\cdot}00^{4}$	$4303{\cdot}00^{5}$	$4303{\cdot}00^{2}$
$4316{\cdot}50^{8}$	$4316{\cdot}60^{2}$	$4316{\cdot}50^{2}$
$4348{\cdot}30^{10}$	$4348{\cdot}20^{2}$	$4347{\cdot}95^{1}$
$4394{\cdot}50^{4}$	$4394{\cdot}50^{3}$	$4394{\cdot}45^{2}$
$4595{\cdot}50^{10}$	$4595{\cdot}40^{3}$	$4595{\cdot}20^{2}$
$4648{\cdot}15^{10}$	$4648{\cdot}15^{4}$	$4648{\cdot}75^{4}$
$4661{\cdot}50^{8}$	$4661{\cdot}50^{4}$	$4661{\cdot}70^{2}$

The subjects presented in this communication may be briefly summed up as follows :—

1. The resort to the process of reflection in producing and photographing solar spectra, and thereby avoiding certain errors, and the employment of the silvered surface itself of a glass grating.

2. The extension of the measurement of oxygen lines into the ultra-violet region.

3. The measurement in the region of less refrangibility than H, of lines of oxygen not heretofore recorded, and the use of projection as a method of measurement.

4. The establishment of a close relationship in position between certain lines in the solar spectrum and the lines of oxygen; the slight differences that exist being assignable to the experimental difficulties in the way of making accurate measures of the oxygen lines, and falling within the limits of error of experiment.

5. The evolution of the fact that the lines of the solar spectrum which appear to correspond to the lines of oxygen are weak, or faint, and show that that gas possesses a feeble absorbent power when compared with metallic vapours or gases like H, Fe, Ca.

6. The demonstration that in Ångström's chart there are many lines not assignable to any elementary body, and that these lines occupy very closely the positions of certain oxygen lines.

7. The suggestion that the proof of the presence in the solar envelopes of oxygen, and other substances giving faint lines, is a problem not to be solved by the comparison of two spectra of small dispersion. The solar spectrum in certain parts is so crowded with lines presenting all kinds of details, that the only satisfactory way is to make measures of the positions of these lines on a large scale, and as truly as possible, and then compare with these the most accurate measures of oxygen lines that can be made.

CYON'S RESEARCHES ON THE EAR[1]

II.

HAVING now described, at what we hope our readers will not consider inordinate length, the history of the subject up to the time when Dr. de Cyon commenced his second series of experiments, a history which he gives in the first part of his thesis in a very clear and impartial manner, we shall now give a short account of the new matter contained in the second part. This may be arranged under two heads—(1) experiments undertaken chiefly with the view of testing the kinetic theory, and (2) the statement of his own theory and arguments in support of it.

The experiments have obviously been made with extraordinary care and skill. Dr. de Cyon succeeded in producing the lesions which he intended to produce, without injuring any other part, and in most cases with scarcely any loss of blood; we can thus observe the effects of any particular operation without the slightest complication from concurrent injury or inflammation of the cerebellum. He has established in the most convincing way, (1) the fact observed by Flourens that the movements of the head always take place "in the plane of the divided canal," or, as we should express it, about an axis at right angles [to that plane. (2) That the movements are much more violent, and that the loss of equilibrium is much more persistent, when the corresponding canals of both sides are cut, than when one only, or two dissimilar canals are divided. (3) That when all six canals are destroyed very violent and complex convulsions occur and continue for several days. If the animal survive this stage it gradually attains a condition in which its movements are effected with great deliberation, and in which the sense of sight is absolutely necessary to enable it to direct itself. These experiments were made upon pigeons, upon rabbits, and upon lampreys, the latter animals being especially interesting as possessing only four canals, two on each side.

So far, the results of the new experiments confirm and render more precise the knowledge derived from previous investigations, and they are in perfect accordance with the kinetic theory. One point, however, requires special notice.

Dr. de Cyon points out that the first movement made by an animal on the section of a canal, takes place in a direction "from the divided canal." It is not quite easy to make out the precise meaning of this phrase. It may, and probably does mean, that when the *left* horizontal canal is cut the pigeon moves its beak to the right; but, as the operator is at the back of the bird, it may also mean that the *back* of the head moves to the right and away from the divided canal. Judging, however, from the experiments upon the vertical canals, it is most probable that Dr. de Cyon means that the first movement takes place in such a manner that the ampulla of the divided canal precedes the canal. If this be the case, and if, as seems reasonable, we assume that the first effect of the division is stimulation and not paralysis, and that the movement is a compensatory one—that is, the result of an effort to preserve the same position—we are forced to the conclusion that the canal is affected by a rotation in which the ampulla *follows* the canal, contrary to the view somewhat hesitatingly expressed by Brown and Mach.

Dr. de Cyon has, however, made several experiments, the results of which cannot so easily be harmonised with the kinetic theory. These experiments were made expressly to test the truth of this theory, and in his opinion their results render it untenable. As Mach holds that change of pressure in the ampullæ excites the ampullary nerves and produces a sensation of rotation, Dr. de Cyon devised and executed a series of experiments so arranged that the pressure in the ampullæ should be changed, without injury to the membranous canals. 1. He opened the bony canal and allowed the perilymph to escape. 2. He opened the utricle and allowed the endolymph to escape, and observed that the whole membranous labyrinth collapsed. 3. He introduced into the space containing the perilymph small rods of dried laminaria; these rods slowly swelled by imbibing moisture, and must have considerably increased the pressure in the interior of the cavity. In none of these cases did he observe any trace of the Flourens phenomena. 4. He replaced the perilymph by a lukewarm solution of gelatine, which solidified, and inclosed the membranous labyrinth in an approximately rigid case. Still no Flourens phenomena were observed, but these at once occurred on pricking the membranous canals through the solid gelatine.

Dr. de Cyon further mentions as an argument against Mach's view, the fact that periodic changes of pressure occur in the contents of the labyrinth, synchronous with the heart's beat, and evidently connected with the change of arterial pressure. This, he thinks should, on Mach's hypothesis, produce irritation of the nerves and sensation. It must, however, be observed, that this change of pressure is produced simultaneously in all the six ampullæ, and that therefore the resultant rotation perceived would be zero.

But by far the most important evidence in opposition to the kinetic theory is derived from the section of the whole auditory nerve. Dr. de Cyon succeeded in performing this operation without serious injury to any other part, and found that rabbits, in which both of the auditory nerves had been divided, and in which, therefore, all nervous connection between the semicircular canals and the brain had been cut off, showed, after being subjected to rotation, the same symptoms of vertigo observed by Mach in the case of normal rabbits. It is unfortunate that Dr. de Cyon has not given further details of this most important experiment.

External irritations which, when small, are perceived only by the organs specially fitted for their perception, as a rule act, when very intense, upon other organs. Thus a feeble sound can

[1] Recherches expérimentales sur les Fonctions des Canaux semi-circulaires et sur leur Rôle dans la Formation de la Notion de l'Espace. Par Elie de Cyon, M.D., &c., Lauréat de l'Institut de France. Continued from p. 635.